Respiratory Self-Gating for Free-Breathing Segmented Cine MRI

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Introduction

Breath-holding continues to be a problematic aspect of cardiac cine-MRI. While real-time techniques can eliminate the need for breath-holding, segmented techniques provide higher SNR, temporal and spatial resolution. Conventional navigator echo (NAV) techniques are not applicable to TrueFISP cine. A new respiratory self-gated (RSG) cine technique derives gating information from projection reconstruction (PR) imaging data. This technique was compared with breath-hold and free-breathing k-space averaging approaches in 6 volunteers in short-axis and long-axis orientations. Qualitative and quantitative metrics demonstrated comparable quality between breath-hold and self-gated images both with significant improvements over simple averaging. Respiratory self-gating shows the potential to remove the need for breath-holding for cine-MRI.

Methods

We propose an approach to free-breathing (FB) segmented cine MRI using PR TrueFISP, similar to a recently introduced method for FB spiral coronary MRA [1,2]. Each sequentially acquired sub-set of radial interleaves provides low-resolution images for region-of-interest (ROI) correlation comparison to reference target images unique to each cardiac phase.

For the FB scans, low-resolution images (3.7x3.7 mm^2 in-plane) were reconstructed from each repeatedly acquired subset of 40 interleaved views using only the central 80 of 192 readout samples. A square ROI for correlation comparison included only cardiac tissue. The scans began with a 20 second FB "target-acquisition" period used to derive respiratory target images for each cardiac phase at expiration. Throughout the remainder of the FB acquisition, each reconstructed low-resolution image was compared to the respiratory target image with the nearest corresponding cardiac phase. Only those views used to reconstruct images having a correlation coefficient above a threshold were included in the final high-resolution reconstruction.

Imaging was performed using a Siemens 1.5T Sonata with a 4-element phased array chest coil and 6-element spine array. Breath-held (BH) and FB acquisitions were performed using a 300 mm^2 FOV, 192 matrix (1.6x1.6 mm^2 in-plane voxel size), 160 views, 3.0 ms TR, 55º flip-angle, 1kHz/pixel BW, and 6 mm slice thickness. For both BH and FB scans, the acquisition of each segment was ended after sufficient views were acquired within each of the 20 cardiac phase temporal windows necessary to reconstruct a 20 image cine series with a temporal resolution of 50 ms.

Six healthy volunteers (N=6) were imaged during BH and FB in short-axis (SA) and long-axis (LA) orientations. All of the raw data acquired during each FB RSG acquisition was additionally reconstructed with the gating threshold set to zero producing an image series representative of simple k-space averaging (AVE), a technique commonly used to overcome difficulties with BH. A quantitative comparison of image sharpness was performed by: 1) plotting a normalized profile across the septum to left-ventricle blood pool (BP) boundary, 2) measuring the distance, *d*, between 0.2*(BP intensity) and 0.8*(BP intensity) across the boundary, and 3) expressing the sharpness as 1/*d* [3]. A qualitative comparison was also performed. Each of the 36 resulting image series were scored (reviewer #1 A.A., reviewer #2 G.H.) for sharpness of definition of fine anatomic structures: 1 (poor), 2 (adequate), 3 (good), and 4 (excellent).

Results

Example SA and LA diastolic phase BH, AVE, and RSG images from a single volunteer are shown in Fig. 1. Notice the blurring of fine anatomic structures in the AVE images and the comparable quality of the BH and RSG images. The FB RSG acquisitions required scan times of 65±22 sec with a scan efficiency of 18.2±7.4 % while the BH scans required scan times of ~12 sec. The image sharpness comparison resulted in mean scores of 0.53±0.08, 0.31±0.10, and 0.52±0.09 (mm^{-1}) for BH, AVE, and RSG respectively with significant ($p<0.05$) differences between RSG and AVE but not between BH and RSG. The qualitative comparison scores from reviewer #1 were 3.58±0.79, 2.25±0.45, and 3.25±0.62 and for reviewer #2 were 3.92 ±0.29, 2.75±0.62, and 3.58±0.67 for BH, AVE, and RSG respectively, with significant ($p<0.05$) differences between BH and AVE as well as between RSG and AVE (Tukey post-hoc).

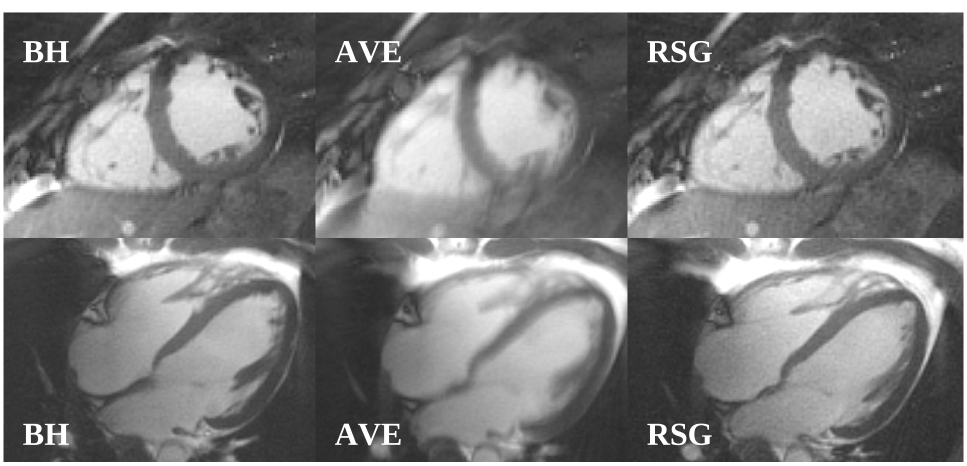

Figure 1. SA and LA images during breath-hold (BH) and during free-breathing reconstructed with averaging (AVE) and respiratory self-gating (RSG). Notice the blurring of fine anatomic structures in AVE images and comparable quality of BH and RSG images.

Conclusion

We have developed an effective respiratory gating method for segmented cine MRI and demonstrated similar image quality to BH techniques as well as significant improvements over simple k-space averaging. In-plane motion correction as demonstrated by Hardy et al. [1] should be possible with this technique allowing decreases in overall scan time and improved scan efficiency. This work is being extended to combine respiratory and cardiac self-gating [4] for "wire-less" free-breathing segmented cine MRI.

[1] Hardy et al. MRM 44:6 2000 940-946
[2] Hardy et al. JMRI 3:17 2003 170-176
[3] Shea et al. JMRI 13:2 301-307
[4] Larson et al. MRM *in-press*